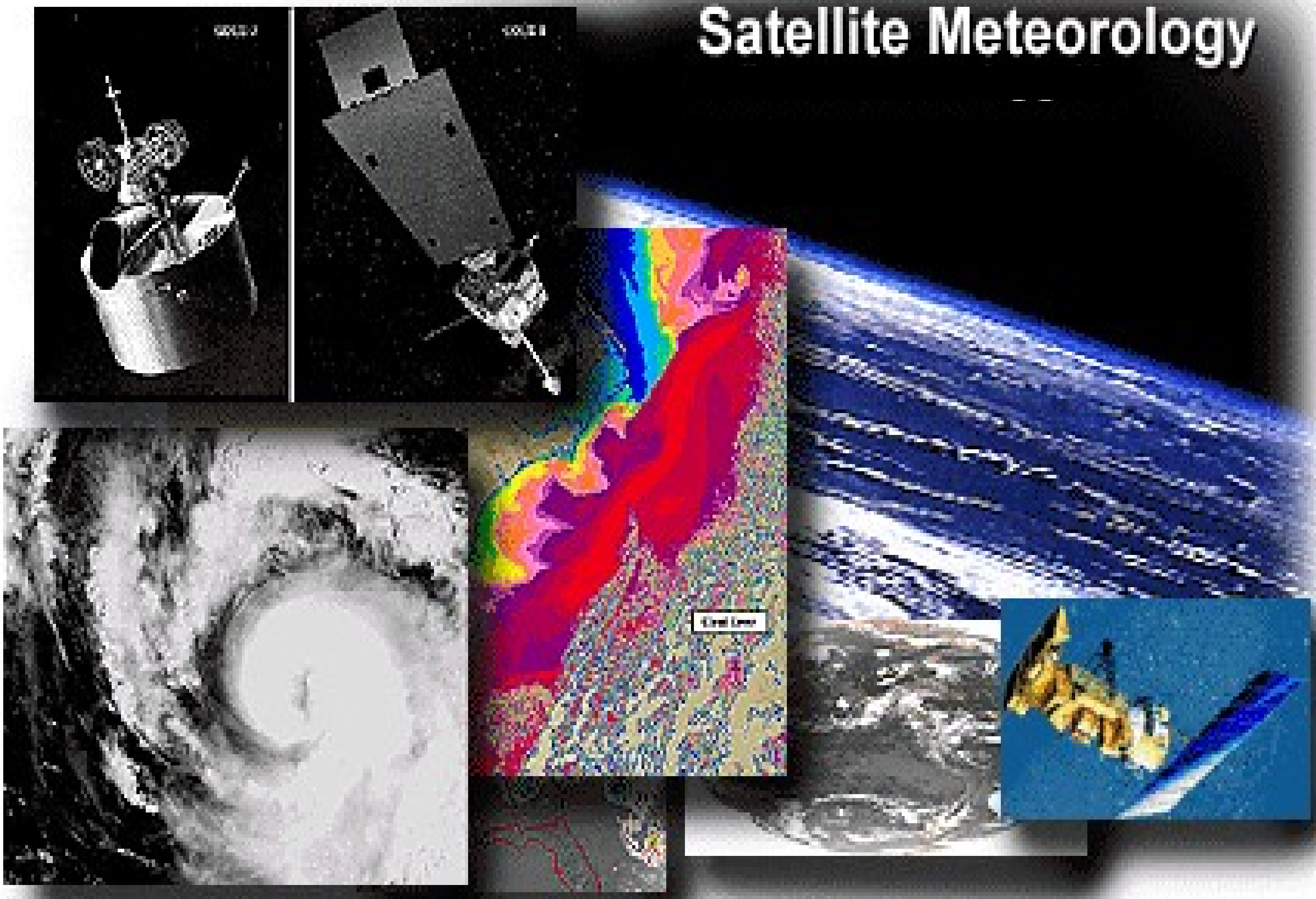
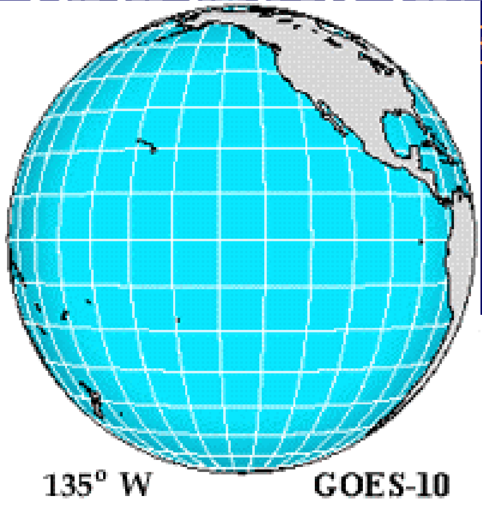

Satellite Meteorology

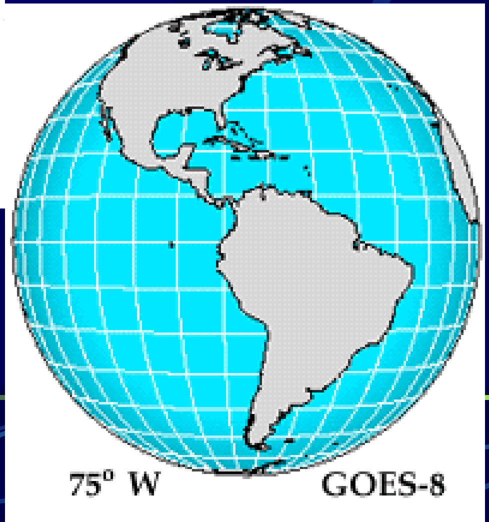
GOES Satellites

geostationary operational environmental satellites

Geostationary Operational Environmental Satellites (GOES) circle the Earth in a geosynchronous orbit over the equator. This means they observe the Earth from the exact same place all the time. This allows the GOES satellites to continuously monitor a single position on the earth's surface. From 35,800 kilometers (22,300 miles) above the earth, GOES satellites provide half-hourly observations of the earth and its environment. Earth coverage of the



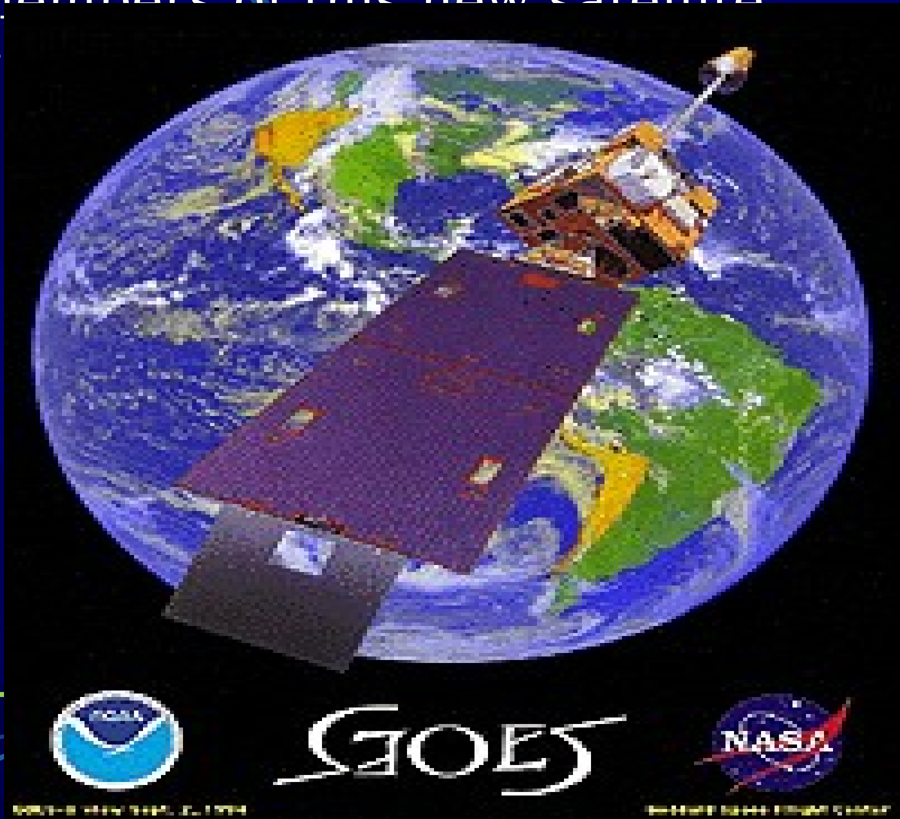
ES-10 satellites has been depicted below.



GOES satellites are owned and operated by the National Oceanic and Atmospheric Administration (NOAA) while the National Aeronautics and Space Administration (NASA) manages the design, development and launch of the spacecraft. Once launched, NOAA once again resumes responsibility for the satellites. There are other geostationary

The first geostationary weather satellite (GOES-1) was launched on October 16, 1975 and quickly became a critical part of the National Weather Service operations. For the past 30 years, environmental service agencies have stated the need for continuous, dependable, timely, and high-quality observations of the earth and its environment. The new generation of GOES satellites, do just that. These satellites have instruments on board that measure Earth-emitted and reflected radiation from which atmospheric temperature, winds, moisture and cloud cover can be derived. GOES-8 and GOES-9 were the first members of this new satellite generation to be launched, replacing orbiters.

The GOES data, which is vital to weather monitoring and short-term forecasting, is then distributed by the National Environmental Satellite and Information Service (NESDIS) to a variety of operational and research centers. Today, GOES data products are used by a wide variety of users; the National Weather Service

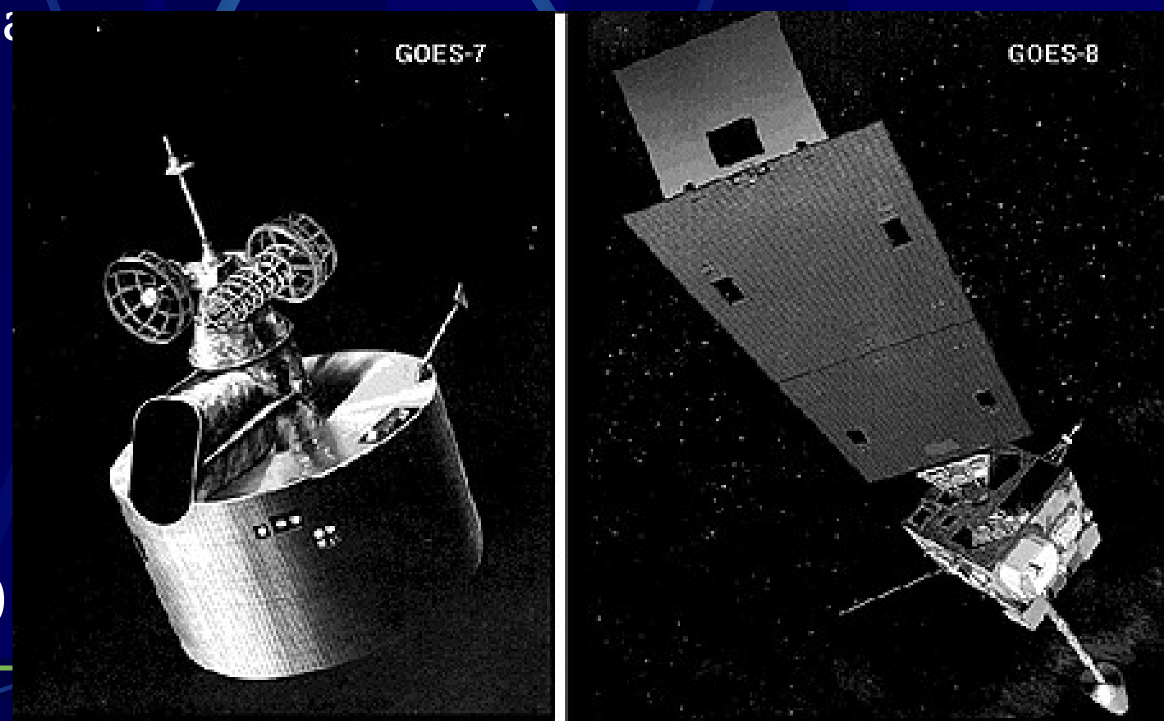


History of GOES

GOES-1 through GOES-7

The first satellite in the GOES program (GOES-1) was launched on October 16, 1975 and quickly became an essential component of services provided by the National Weather Service. From the earliest days of the GOES program, implementing satellite imagery to perform such tasks as tracking hurricanes and volcano ash, as well as deriving cloud drift winds and their temperatures, were (and still are today) used by operational forecast centers to help with analyses in data sparse area

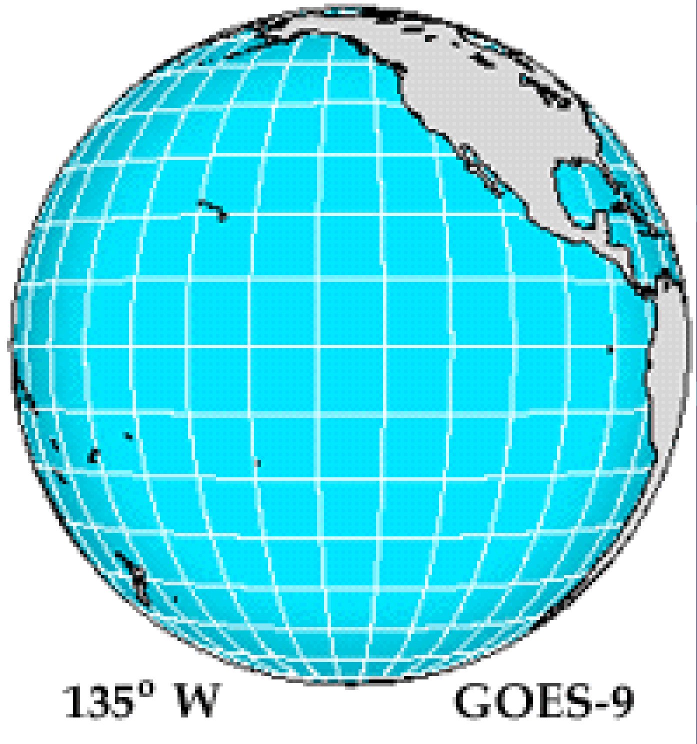
The newer satellites have benefited from the experiences of the other seven (GOES-1 through GOES-7) and results are shown through their improved capabilities. GOES-7 (pictured below) was only recently discontinued in 1995

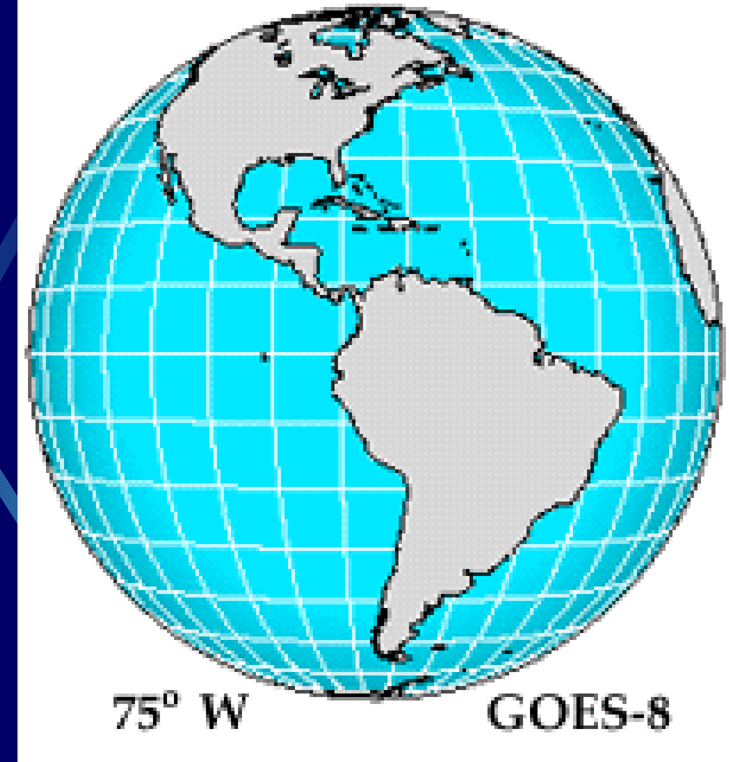


GOES-8 and GOES-10 fully operational

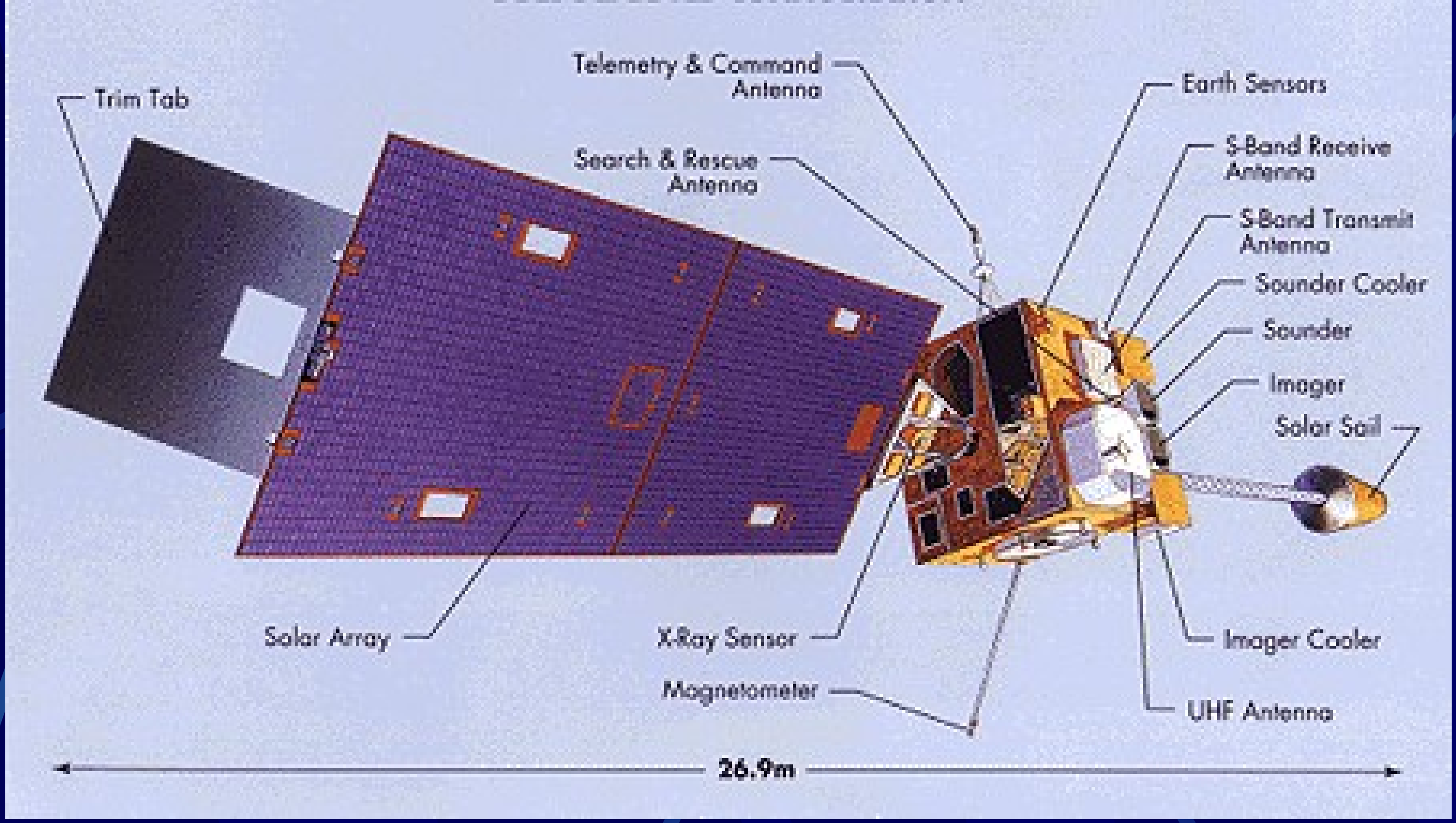
Currently the US operates two geostationary satellites (GOES-8 and GOES-10) in geostationary orbit over the equator.

The GOES-8 is located at 75 west longitude above the equator and it covers North and South America and most of the Atlantic Ocean. The GOES-10 is also located above the equator at 135 west longitude and it monitors North





Both satellites carry imager and sounder instruments. The three-axis, body stabilized spacecraft design enables the sensors to image clouds, monitor earth's surface temperature and water vapor fields, and sound the atmosphere for its vertical thermal and vapor structures. GOES-8 and GOES-10 also introduce two new features: flexible scanning that allows

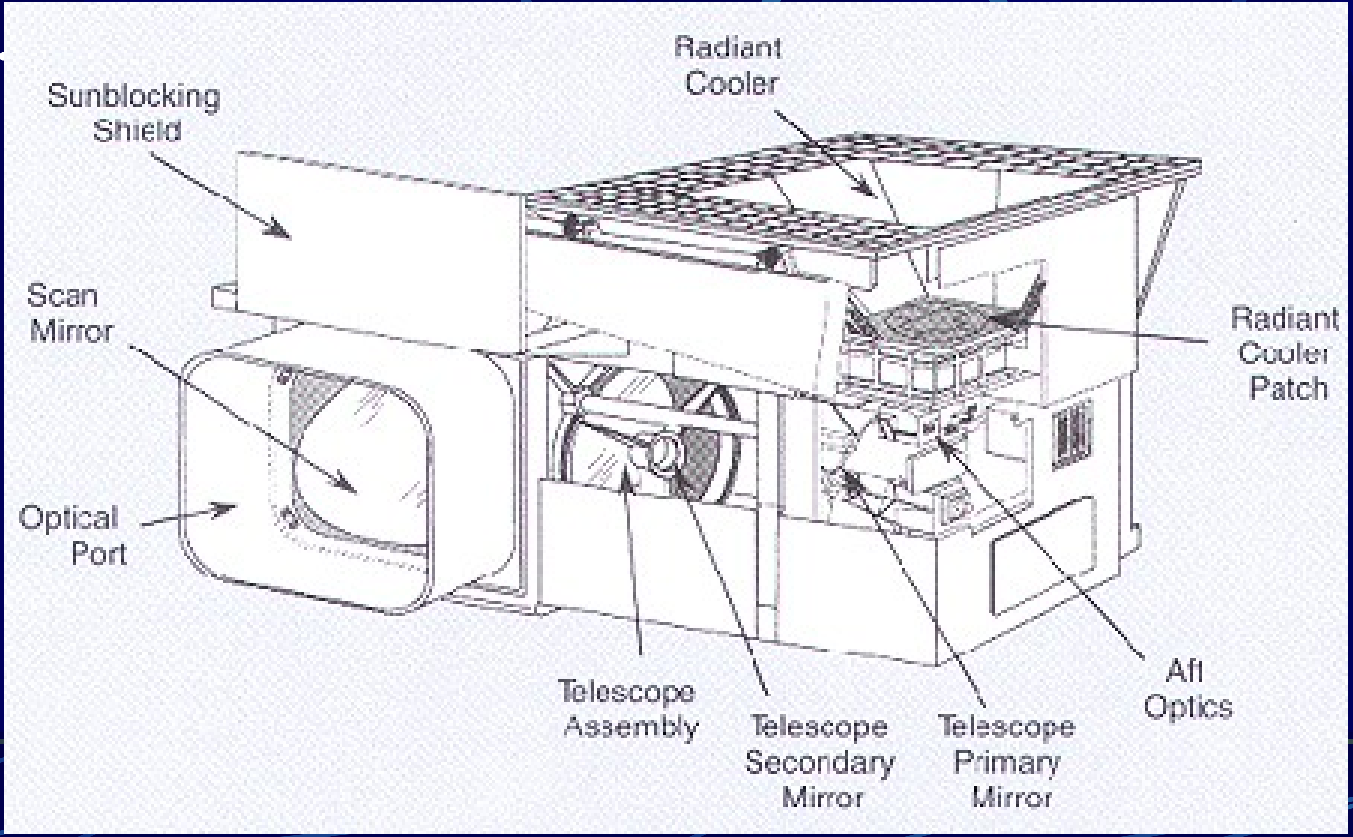


The components of a deployed GOES satellite are labeled in the diagram above. The main body has dimensions of 2.0 x 2.1 x 2.3 meters (m) and when the solar array deployed, the satellite is 26.9 meters long. The craft weighs 2104.7 kilograms (kg) and has a minimum lifetime of 5 years. GOES-8 was launched on April 13, 1994 and GOES-10 followed on May 23, 1995. GOES-10

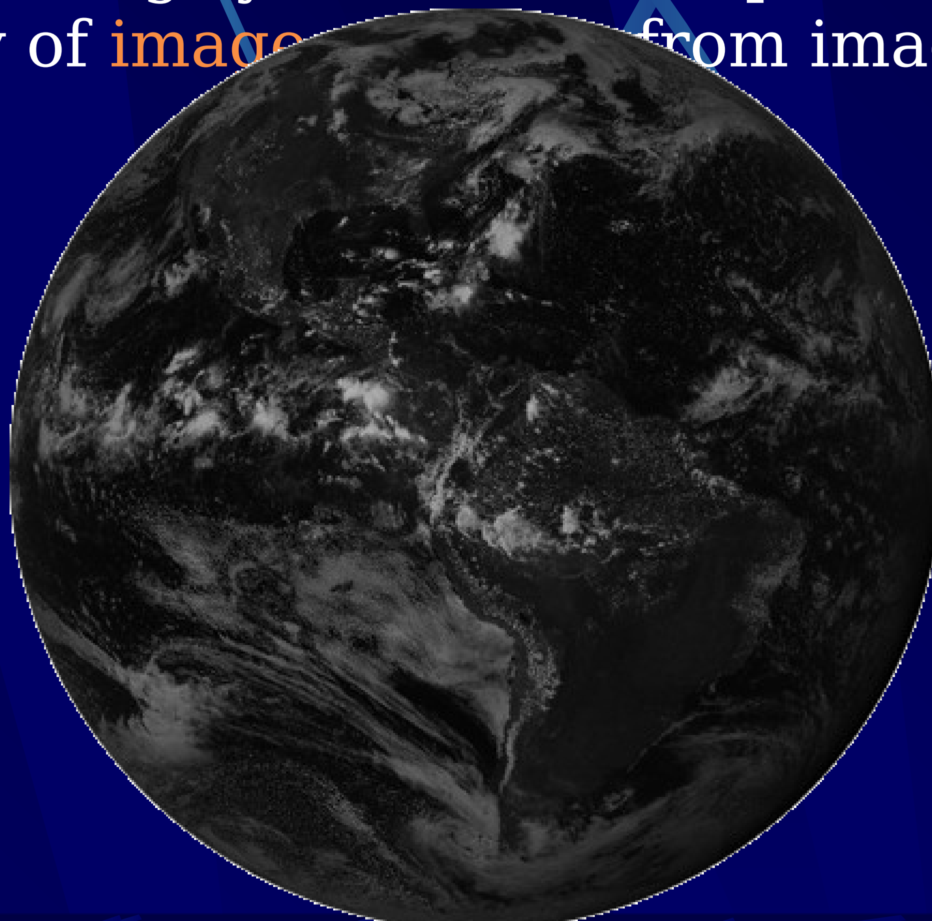
GOES Imager

multi-channel energy sensor

The GOES Imager is a multi-channel instrument designed to sense radiant and solar-reflected energy from sampled areas of the Earth. The multi-element spectral channels simultaneously sweep east-west and west-east along a north-to-south path by means of a two-axis mirror scan system.



The instrument can produce full-Earth disc images, sector images containing the edges of the Earth, and various sizes of area scans completely enclosed within the Earth scene using a new flexible scan system. A five-channel monitoring system makes it possible to produce a wide variety of imag from imager data.



One such example is this visible full-Earth disc image

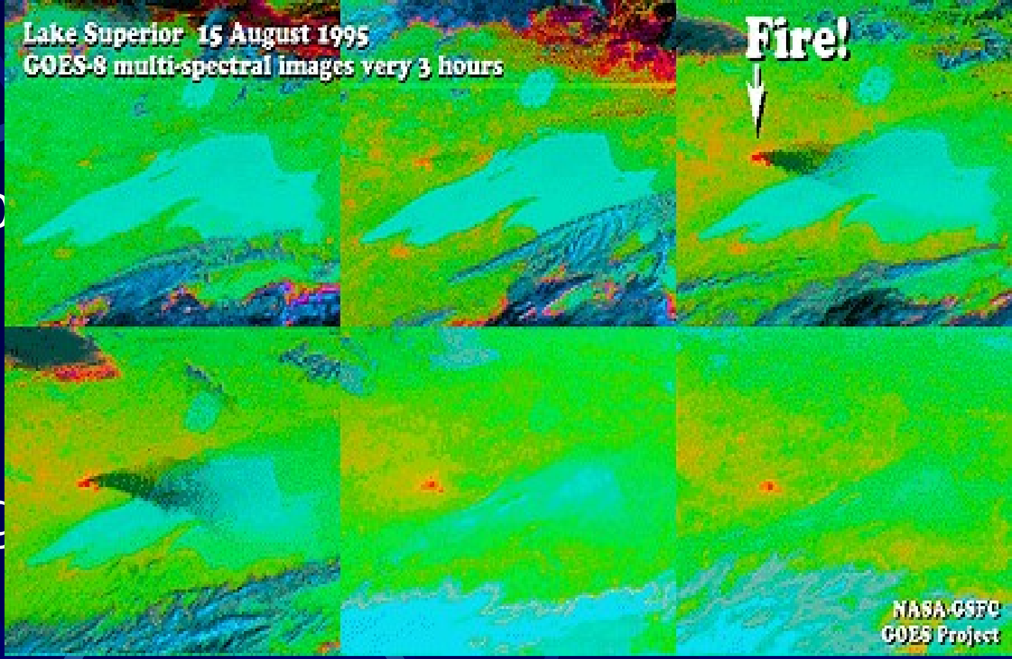
GOES Imager Products

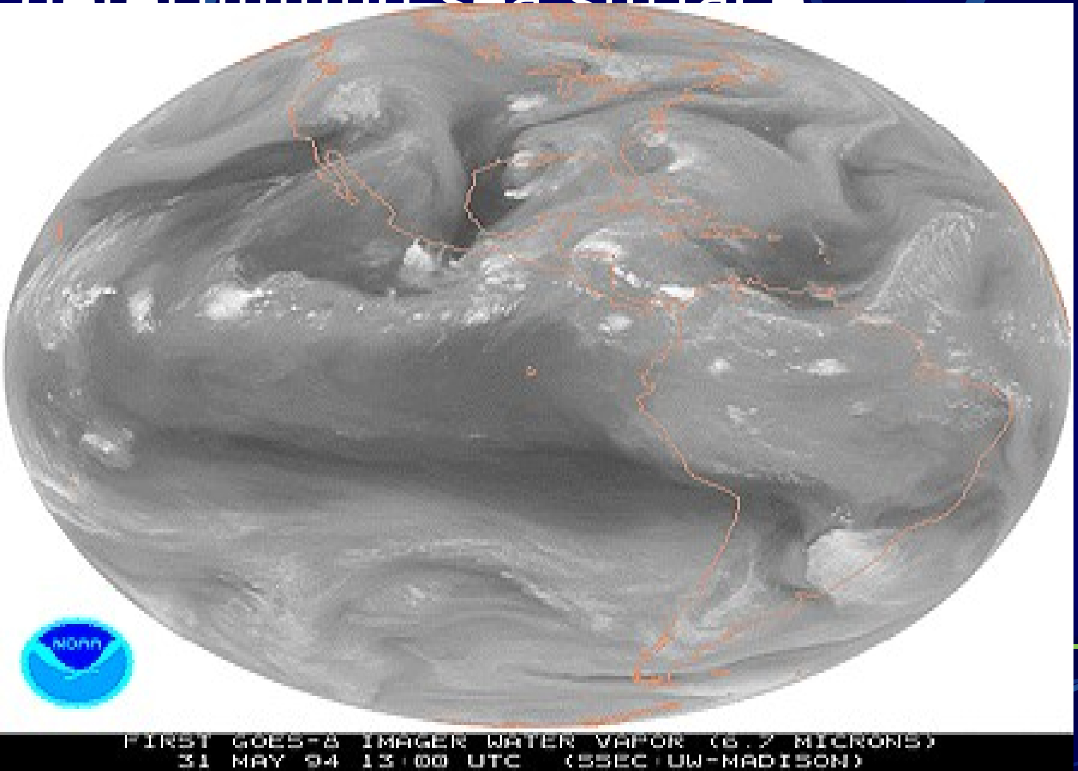
products generated from imager data

The imager detects different wavelengths of energy through different channels. This allows the imager to capture visible light, emitted long wave radiation and other radiation wavelengths. The imager has five "channels" which monitor radiation at a specific wavelength per given channel. Channel and product descriptions are given below:

0.52 - 0.72 micrometers (visible) - at 1 km, useful for cloud, pollution, and haze detection and severe storm identific

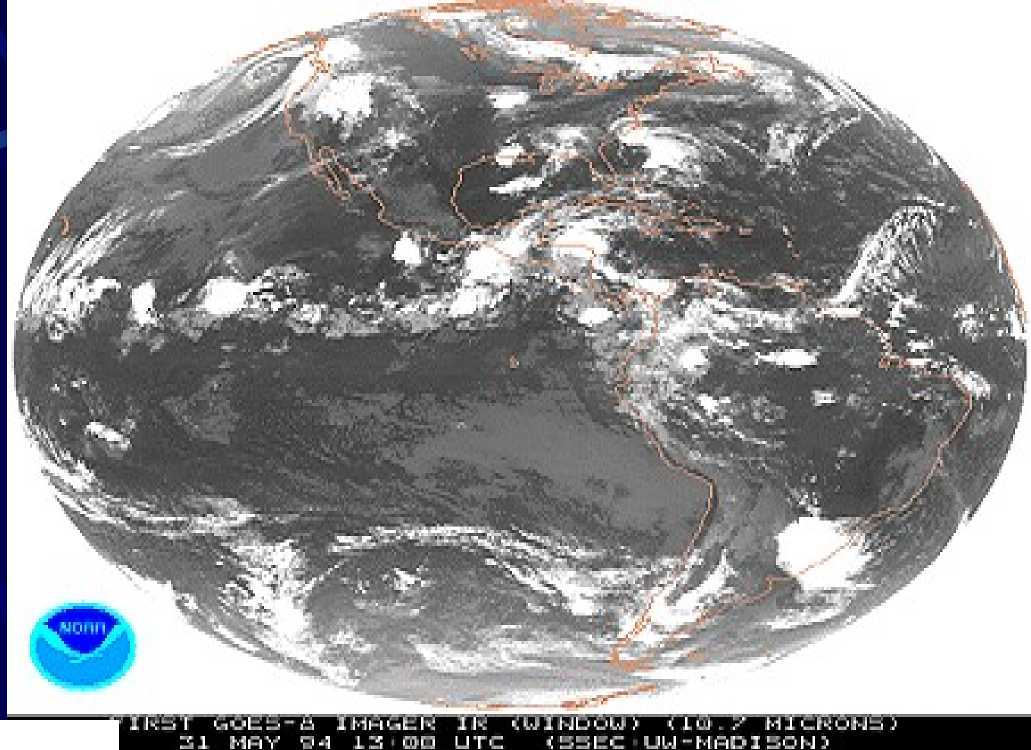
3.78 - 4.03 micrometers (short wave infrared window) - at 4 km, useful fo identifying fog at night, discriminating between water clouds and snow or ice crystal clouds, detecting fires and volcanoes, and determining sea surface

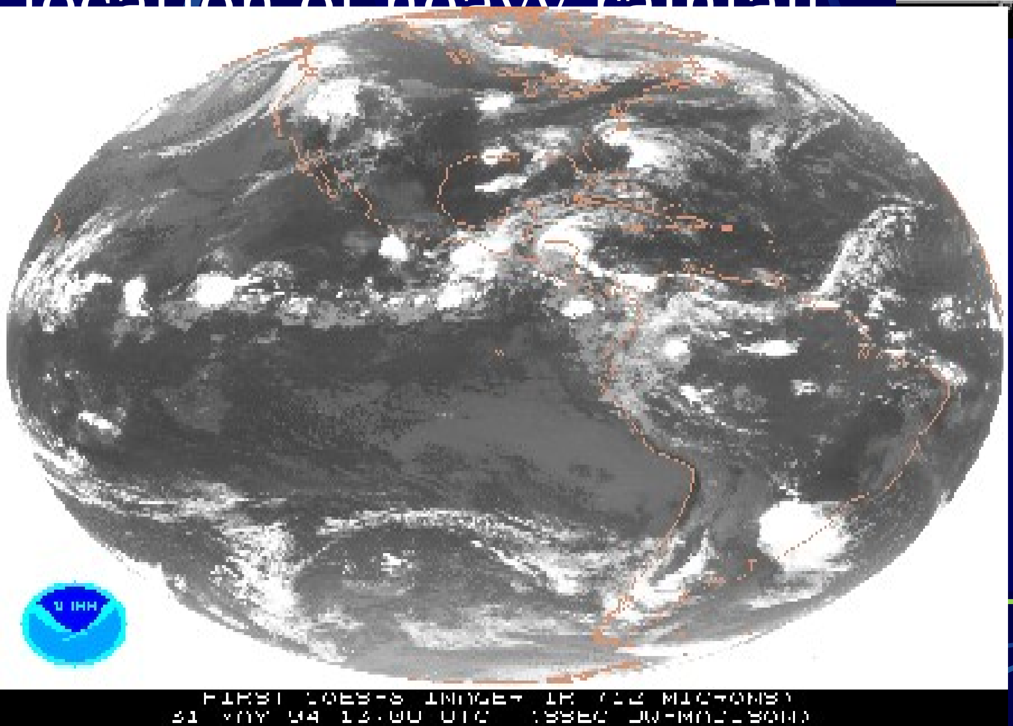




6.47 - 7.02 micrometers (upper level water vapor) - at 4 km, useful for estimating regions of mid-level moisture content and advection

10.2 - 11.2 micrometers (long wave infrared window) - at 4 km, familiar to most users for cloud-drift winds, severe storm identification, and location of heavy rainfall



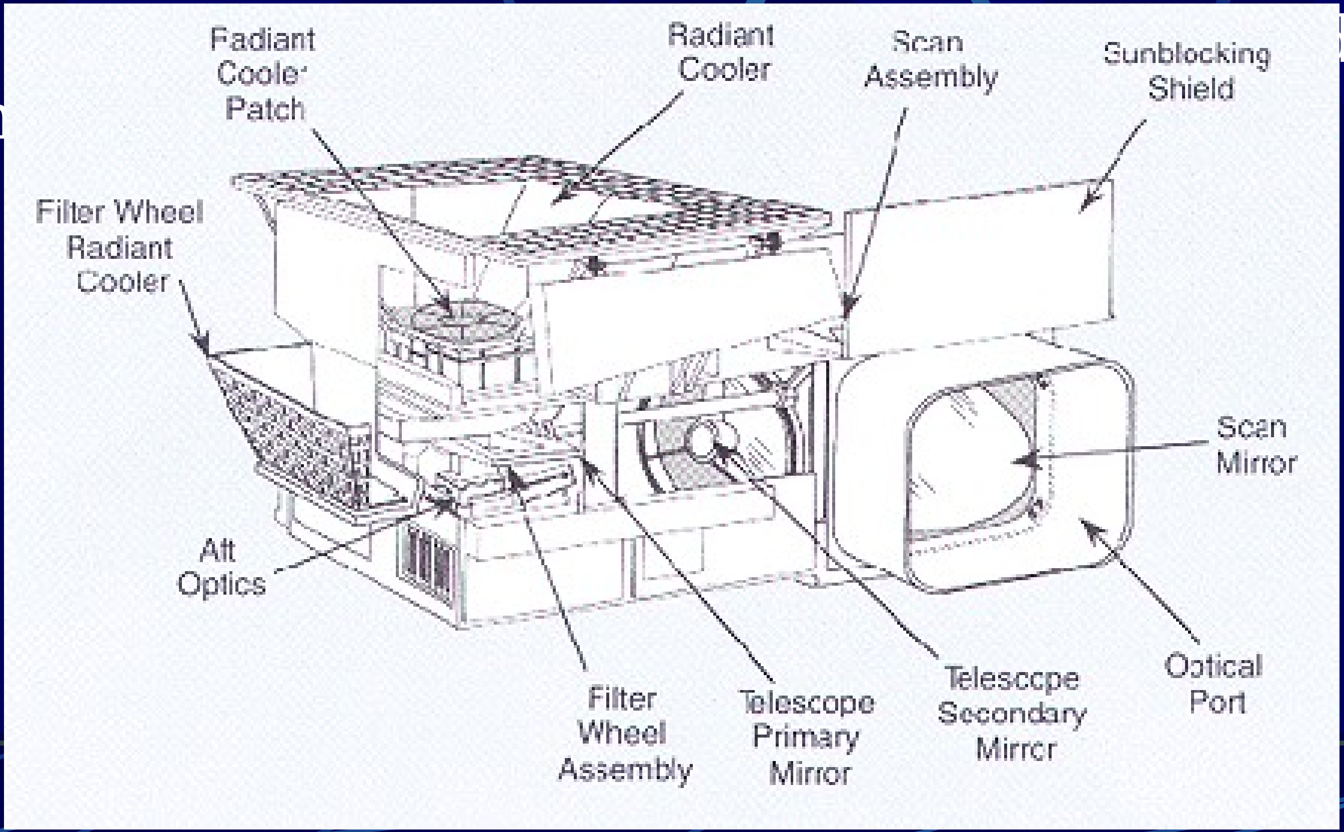


11.5 - 12.5 micrometers (infrared window more sensitive to water vapor) - at 4 km, useful for identification of low-level moisture, determination of sea surface temperature, and detection of airborne dust

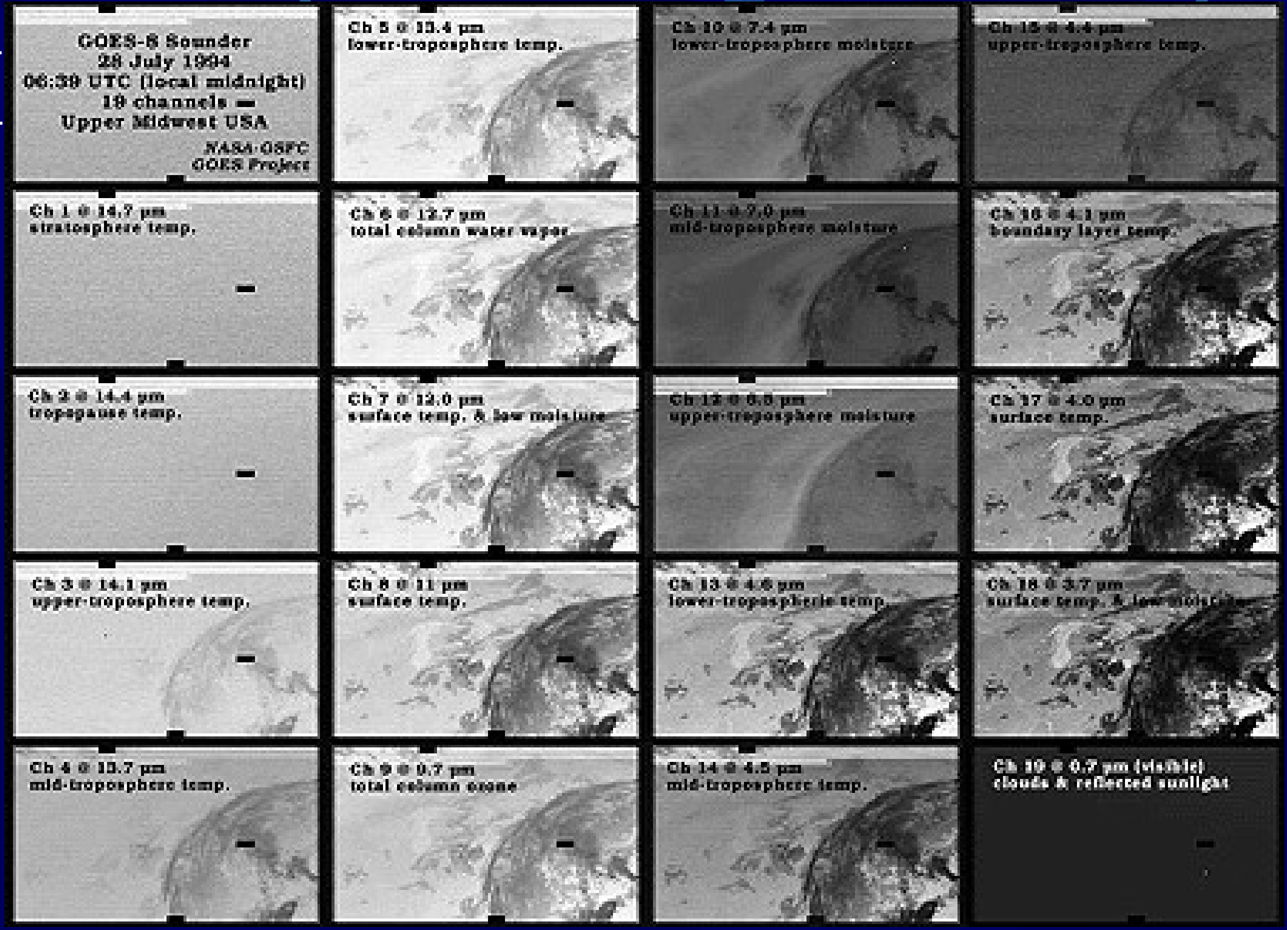
GOES Sounder

radiometer for producing atmospheric vertical profiles

The GOES Sounder is a 19-channel discrete-filter radiometer covering the spectral range from the visible channel wavelengths to 15 microns. It is designed to provide data from which atmospheric temperature and moisture profiles, surface and cloud-top temperatures and pre[...]duced by mathem[...]



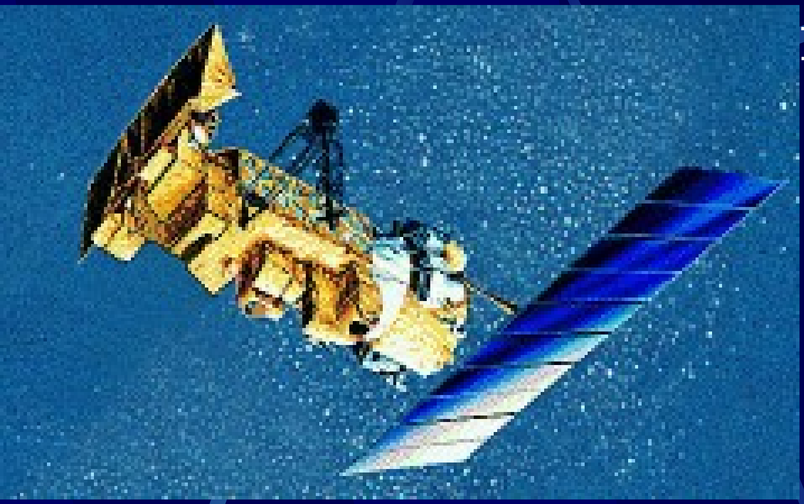
It operates independently of and simultaneously with the Imager, using a similarly flexible scanning system. The sounder's multi-element detector array assemblies simultaneously sample four separate fields or atmospheric columns. A rotating filter wheel, which brings spectral filters into the opti
infrared cha



Above is a collection images from sounder data of the midwestern United States on 28 July 1994 at 0630 UTC, as viewed through the

Polar Orbiting Satellites

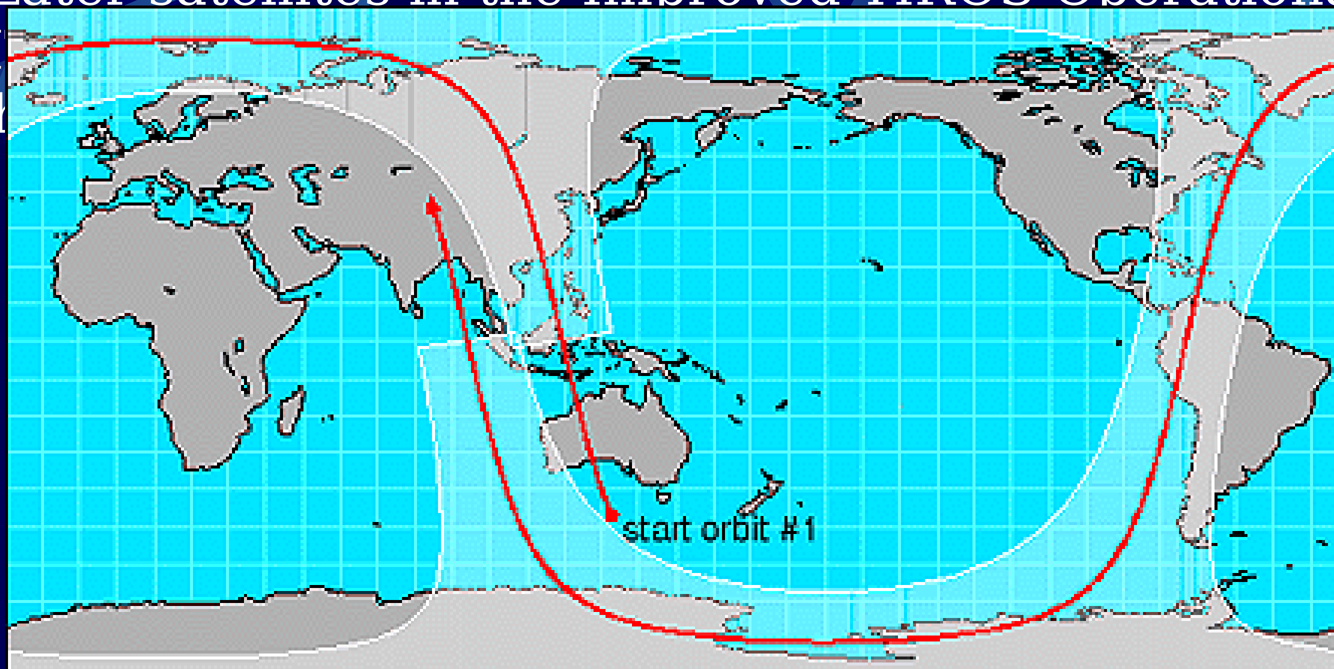
the POES
rogram



Polar-Orbiting Environmental Satellites (POES) are placed in circular sun-synchronous (see below) orbits and their altitudes usually range from 700 to 800 kilometers, with orbital periods of 98 to 102 minutes.

POES satellites include:
Defense Meteorological Satellite Program (DMSP), Landsat, SPOT and
NOAA Polar-orbiting Operational Environmental Satellit es (NPOES)
. The DMSP and NPOES satellites are operational meteorological satellites. Imagery from successive orbits overlay each other, providing global daily coverage from each satellite. Commercial polar orbiters like Landsat

POES have meteorological and geophysical importance because of their high-resolution global coverage and well calibrated channels. They are designed to stay in a low earth orbit and reach high latitudes. The POES program began in 1960 with the launch of TIROS-1. Later satellites in the Improved TIROS Operational
Satellite (I ent
multiple-c



The POES orbit (above) relative to the Earth's surface is sun-synchronous. Its track is due to a combination of the orbital plane of the satellite coupled with the rotation of the Earth beneath the satellite. The orbit is slightly tilted towards the northwest and does not actually go over the poles. The red path follows the earth track of the satellite, the transparent overlay indicates the coverage area for the Advanced Very High Resolution Radiometer (AVHRR)

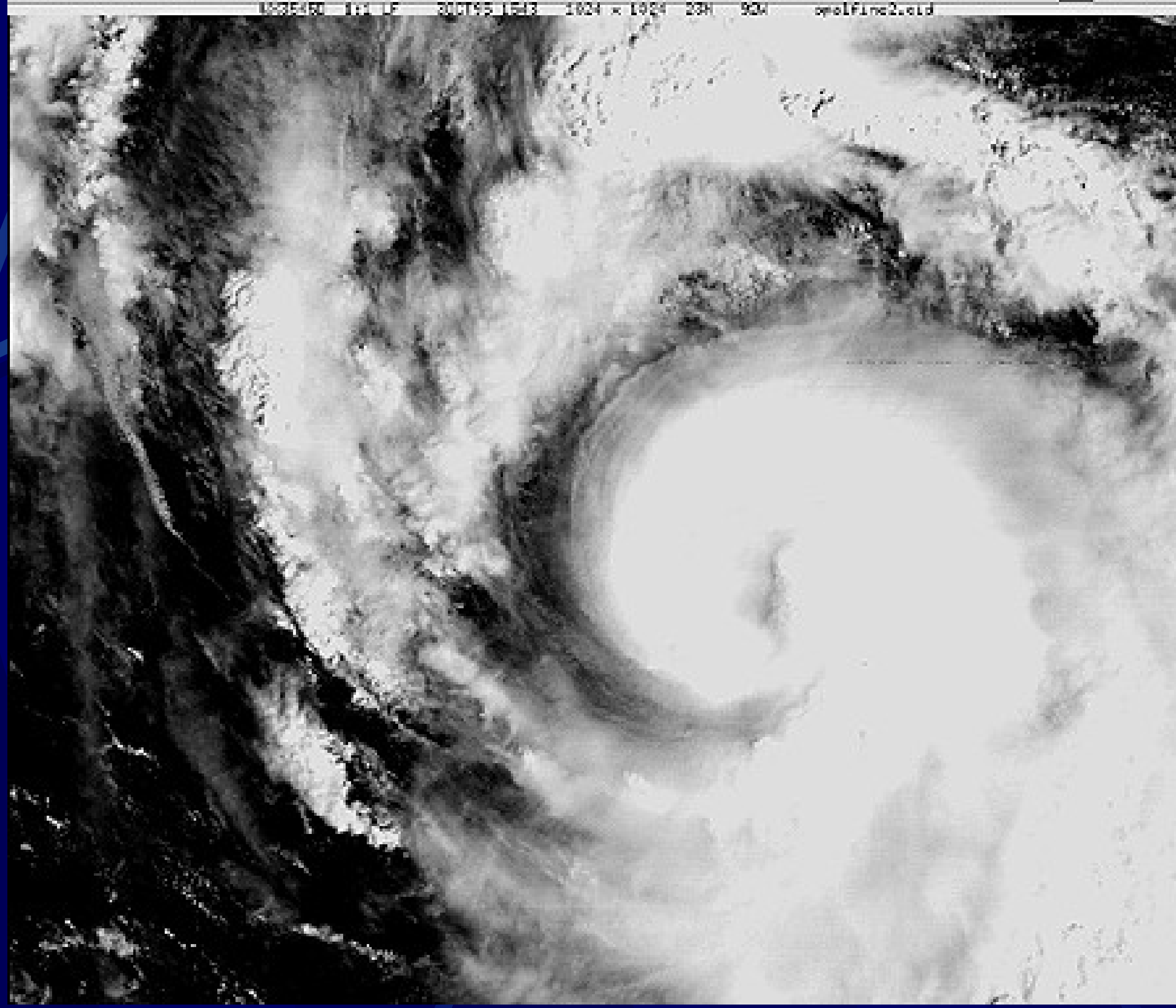
DMSP
POES

run by the department of defense

The Defense Meteorological Satellite Program (DMSP) is run by the Air Force Space and Missile Systems Center (SMC)

The DMSP program designs, builds, launches, and maintains several near polar orbiting, sun synchronous satellites monitoring the meteorological, oceanographic, and solar-terrestrial physics environments.

DMSP satellites are in a near polar, sun synchronous orbit approximately 830 kilometers above the earth. Each satellite crosses any point on the earth twice a day and has an orbital period of about 101 minutes, thus providing complete global coverage every six hours. Each DMSP satellite monitors the atmospheric, oceanographic

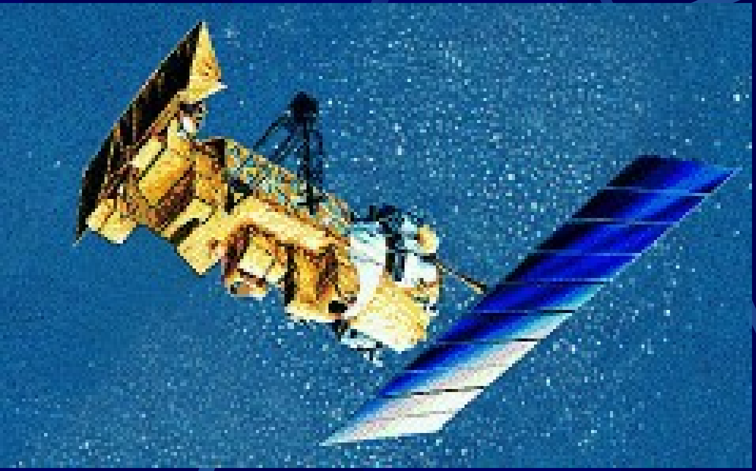


These satellites have capabilities to zoom in close to atmospheric phenomena (like hurricanes). Other capabilities of DMSP satellites include the detection of: lightning, biomass burning, aurora, snow, ice and even city lights.

The image above reveals where the lights are in the US when the sun goes down. The data from the DMSP satellites are received and used at operational centers on a continual basis. The data are sent daily to the National Geophysical Data Center (NGDC) and Solar

NOAA POES

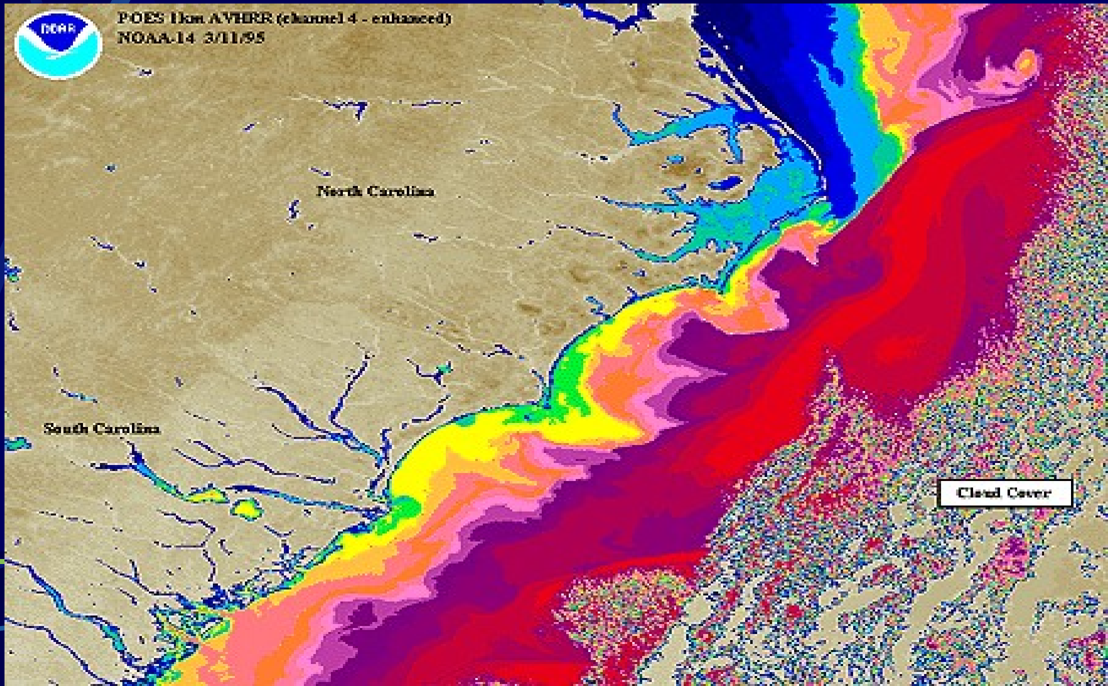
run by noaa



NOAA Polar-orbiting Operational Environmental Satellites (POES) are three-axis-stabilized spacecrafts that are launched into an orbit 830-870 kilometers high, constantly circling the Earth in an almost north-south orbit, passing close to both poles. POES satellites from NOAA-6 offer 4 or 5 channel multispectral daily repetitive global coverage.

The NOAA-12 -14 belong to the TIROS series known as the advanced Television Infrared Observing System satellite (The first meteorological satellite was one of the TIROS family).

They operate as a pair to ensure that data for any region of the Earth is no more than six hours old. More than 16,000 global measurements are sent daily to NOAA's Command and Data Acquisition areas and are used for forecasting models. Additional capabilities of these satellites include fire plume detection (above) and sea surface temperatures (image below).



NOAA's POES satellites continue to carry the Advanced Very High Resolution Radiometer (AVHRR) which is a four or five channel scanner (depending on the model). AVHRR data are acquired in three formats:

High Resolution Picture Transmission (HRPT)
Full resolution (1.1 km) image data transmitted to a ground station as they are collected.

Local Area Coverage (LAC)
Full resolution data, but recorded with an on-board tape recorder for subsequent transmission during a station overpass.

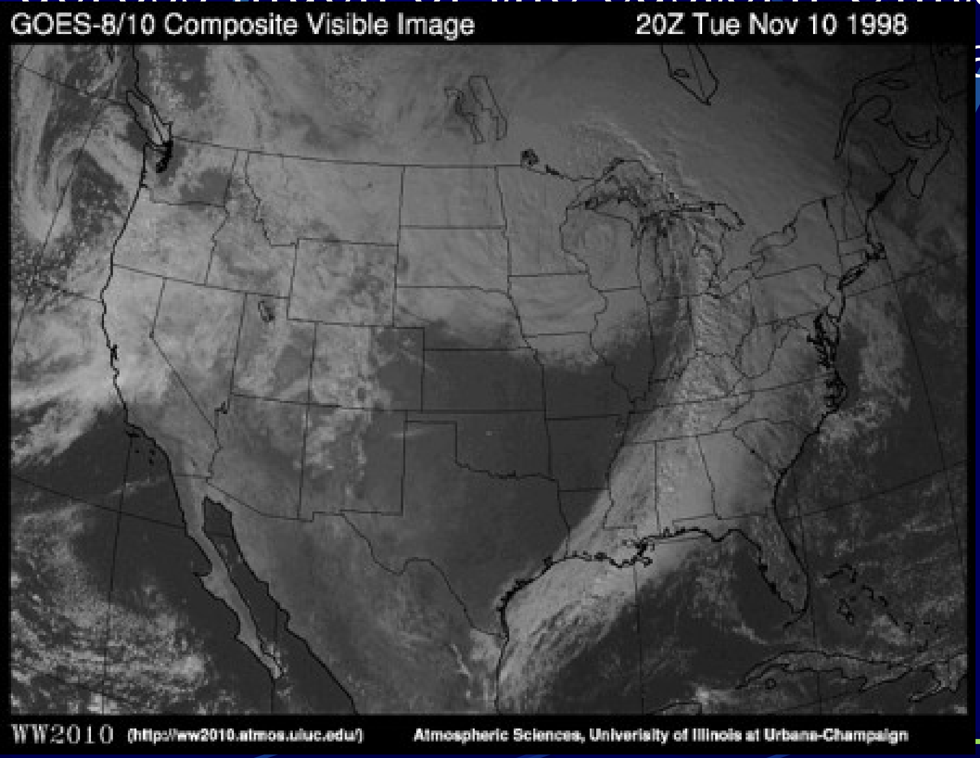
Global Area Coverage (GAC)
Daily subsampled (4 out of 5 samples included) global coverage recorded on tape recorders then transmitted to a ground station.

A new series of polar orbiters, with improved sensors, will began with the launch of NOAA-k (NOAA-15) in

Visible Satellite Images

a picture of the earth

Visible satellite images are photographs of the earth that provide information about cloud cover. Areas of white indicate clouds while shades of gray indicate generally clear skies. In the example below (a composite of data from GOES-8 and GOES-10 satellites), scattered clouds are found across much of the eastern United States with clearer skies ahoma.

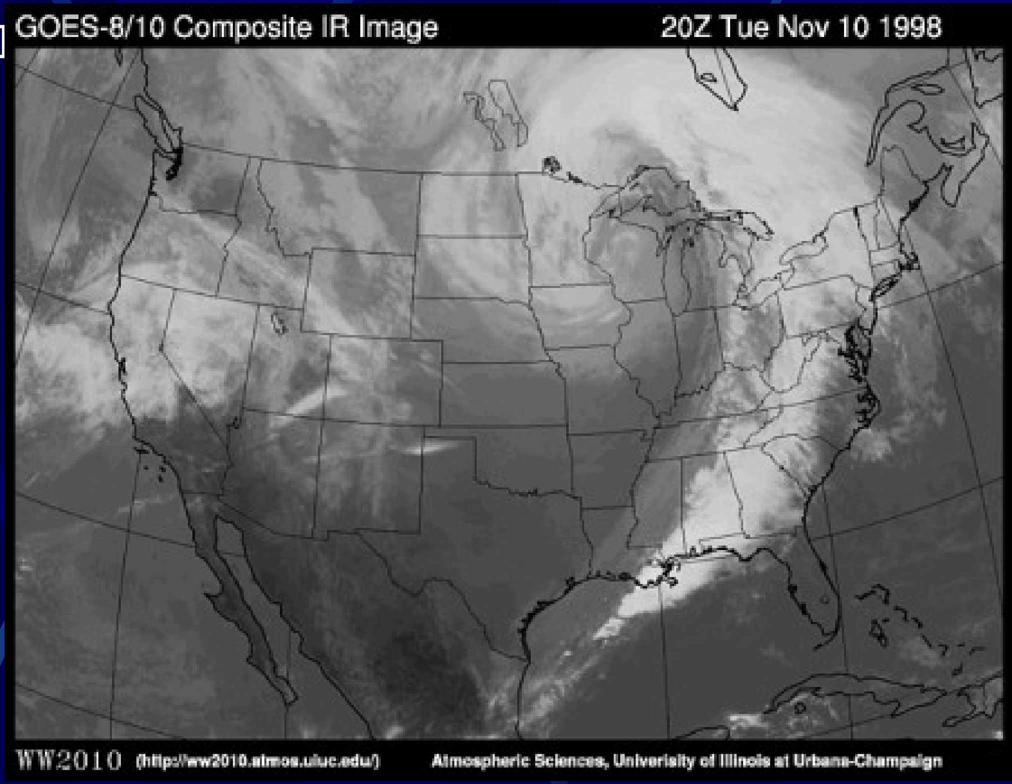


Visible images represent the amount of sunlight being scattered back into space by the clouds, aerosols, atmospheric gases, and the Earth's surface. Thicker clouds have a higher reflectivity (or albedo) and appear brighter than thinner clouds on a visible image. However, it is difficult to distinguish among low, middle, and high level clouds in a visible satellite image, since they can all

Infrared Satellite Images

estimating temper

Infrared satellite measurements are related to the brightness temperature. For an infrared picture, warmer objects appear darker than colder objects, as in the example below (a composite of data from GOES-8 and GOES-10 satellites).



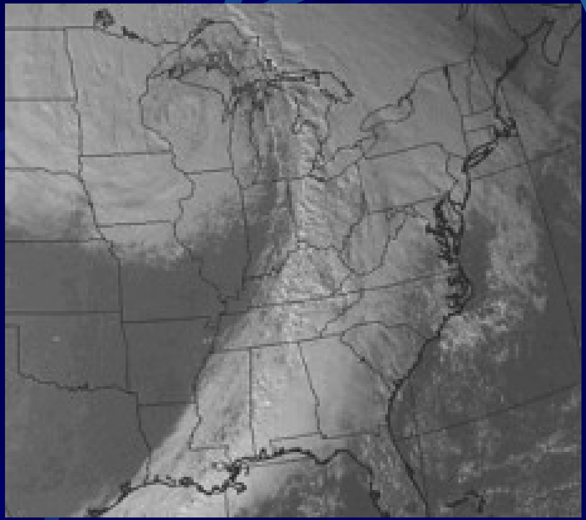
Since temperature in the troposphere decreases with height, high level clouds are colder than low level clouds. Therefore, low clouds (like those found over North Carolina and Virginia) appear darker on an infrared image and higher clouds (like those found throughout the eastern U.S.) appear brighter. The very dark shades of gray in parts of the Rocky Mountains and

Visible -vs- Infrared Images

comparison and contrast

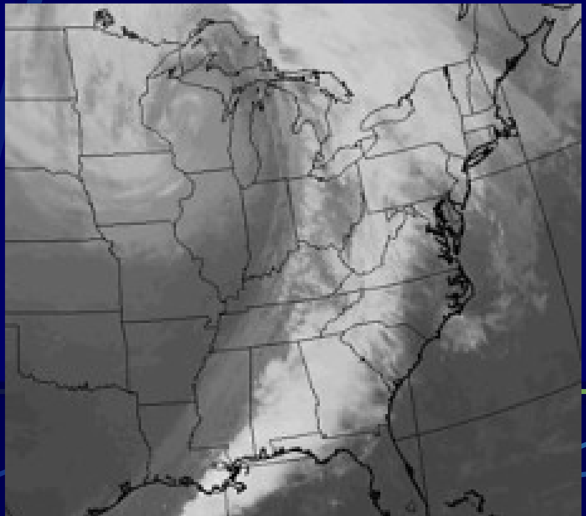
Images (a) and (b) are examples of visible and infrared satellite images respectively (valid for the same time).

(a)



Visible images measure scattered light and the example here depicts a wide line of clouds stretching across the southeastern United States and then northward into Ontario and Quebec.

(b)



In contrast, infrared images are related to brightness. Therefore, the clouds over Louisiana, Mississippi, and western Tennessee in image (a) appear gray in the infrared image (b) because of they are lower and have relatively warm cloud tops. The warmer the temperature, the lower

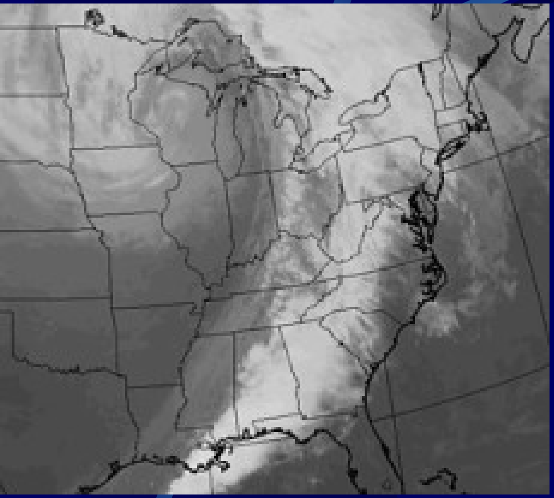
From Alabama northeastward into New York is a region of deep convective clouds that appear bright white in both pictures. Because of their higher cloud tops, these clouds are bright white in both images because of their high reflectivity and extremely cold cloud top temperatures.

The clouds in Canada probably high thinner cirrus and cirrostratus clouds. They have lower reflectivities and therefore appear somewhat darker in the visible image (a) but because of their higher altitudes and colder cloud tops, they appear bright white in the infrared image (b).

Color Enhanced Infrared Images

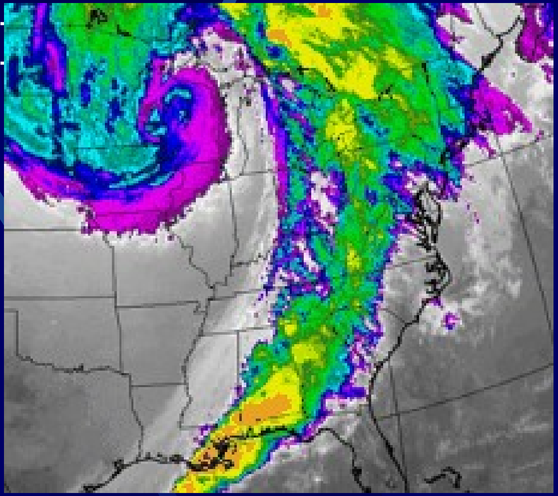
color enhancement of colder temperatures

Images (a) and (b) are examples of gray-scale and color enhanced infrared satellite images respectively (valid for the same time).



(a)

In this infrared image (a), the thunderstorms erupting from the Gulf of Mexico into New York ap... the same height.



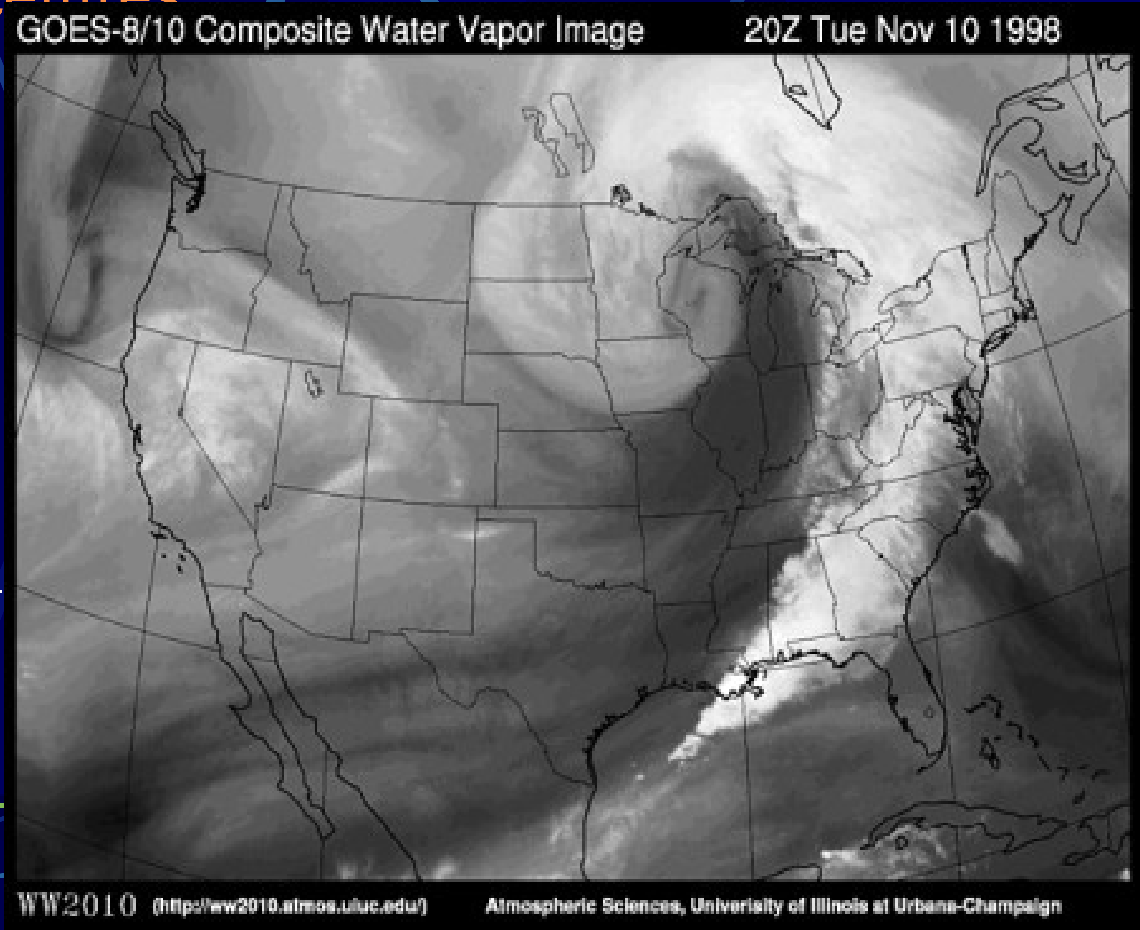
(b)

Color enhancement is a procedure where specified levels of energy -- in this example, infrared energy -- are given a specific color. this makes locations with the desired energies easier to locate. In this example (b), shades of yellow and orange represent infrared energy emissions consistent with strong thunderstorms. This is because infrared energy is proportional to brightness temperature, and the highest cloud tops are colder than those at lower altitudes (the

Water Vapor Images

estimating moisture

Water vapor images are useful for pointing out regions of moist and dry air, which also provides information about the swirling middle tropospheric wind patterns and jet streams. The example below is a composite of data from GOES-8 and GOES-10 satellites.

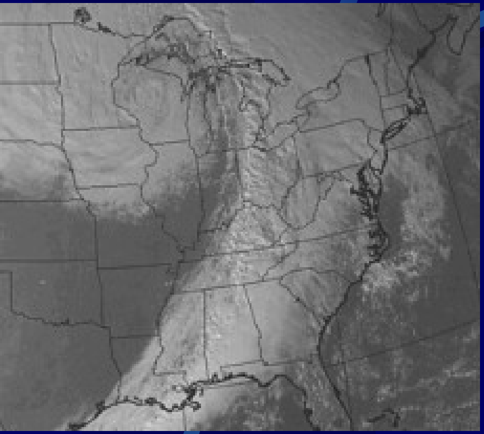


Darker colors indicate drier air while the brighter the shade of white, the more moisture in the air. In the image above, very dry air was present from Oklahoma into Illinois (indicated by the dark colors). Bright white plumes stretching from Missouri to South Carolina indicate the very

Visible -vs- Infrared -vs- Water Vapor

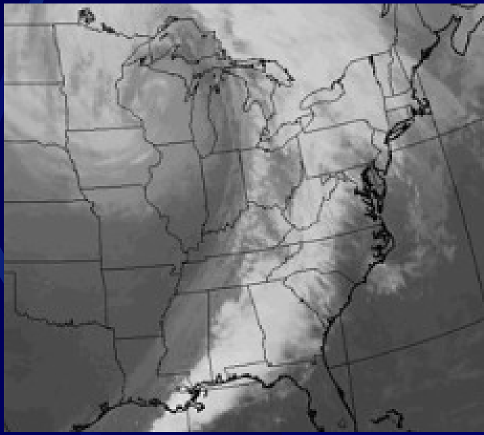
reflectivity -vs- temperature -vs- moisture

Images (a), (b) and (c) are examples of visible and infrared and water vapor satellite images respectively (valid for the same time).



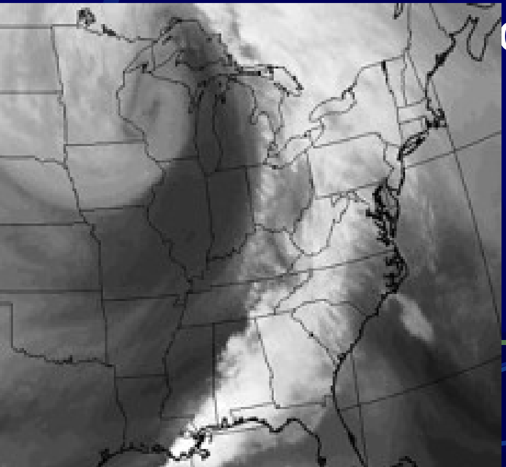
(a)

The visible image depicts clouds stretching from the Gulf of Mexico northeastward into Canada.



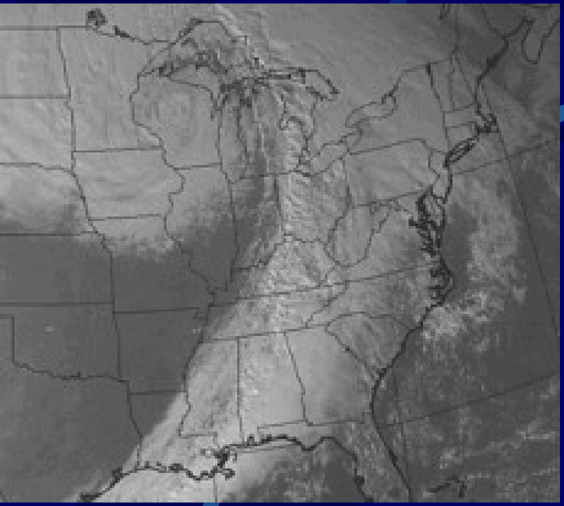
(b)

The clouds over Louisiana, Mississippi, and western Tennessee appear gray in the infrared image because of their low and relatively warm cloud tops. The warmer the cloud top the darker the color.

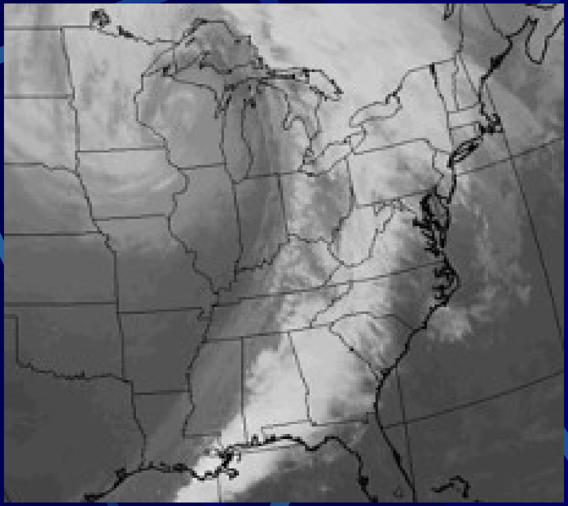


(c)

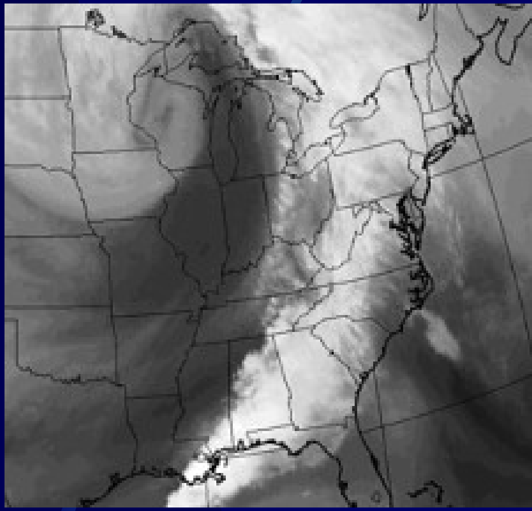
These clouds are associated with a large area of moist air covering most of the eastern third of the United States visible in the water vapor image as the extensive area of white.



(a
)



(b
)



(c
)

The thunderstorms (areas of bright white) that broke out from Missouri to South Carolina stand out more vividly in the infrared and water vapor images than in the visible. Drier air filtering in behind the thunderstorms across Illinois, Indiana and Missouri stands out very well in the water vapor image (c), however is not as noticeable in